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THE ECOLOGICAL RELATIONS OF THE VEGETATION OF WESTERN TEXAS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXX.

WILLIAM L. BRAY.

(WITH TWENTY-FOUR TEXT FIGURES)

[*Continued from p. 123.*]

THE GREAT PLAINS.

THIS great region is naturally divided into two sub-regions, (1) the prairie plains, from which, except for scattered remnants, the original Great plains deposits have been removed, and embraced in the central and east central provinces of Hill (*fig.* 1); and (2) the remaining areas of Great plains proper (Llano Estacado, Edwards plateau, and Stockton plateau).

The prairie plains.—This sub-region embraces the grass country of central and north Texas west of meridian 97.5°, an area over 50,000 square miles in extent. As previously stated, it is a vast region of denudation, presumably from a former plain which must have stood at a much higher level. Whatever may have been the overlying formations, the present stage of erosion presents exposures of various formations, each of which owes its individuality chiefly to the character of the strata now undergoing reduction. Taken as a whole the dominant vegetation is a grass formation, but upon the areas of sand and gravel exposure, and the hills, bluffs, and streamways, timber formations prevail. The provinces are the Grand prairie and those of the central denuded region, embracing (1) the granite country, (2) the Carboniferous area (Brownwood and Palo Pinto countries), (3) the upper cross timbers, (4) the red beds country, and (5) the Callahan divide.

THE GRAND PRAIRIE—Geologically this is a Lower Cretaceous area extending from the Colorado river (its eastern margin near Austin) northward beyond the Red river, its eastern boundary being the Black prairie or rich black land area of Texas. The western boundary of this province is a prominent and irregular escarpment overlooking the central denuded region, and the upper cross timbers at the north. The prairies, which are the dominant physiographic feature, are wide undulations interrupted by broad erosion valleys and occasional butte remnants of the former plain. The elevation of the province is from 800 to 1200 feet. The soil covering is but a thin veneering overlying alternating beds of chalky limestones and marls, which are very poor receivers or retainers of moisture. This condition suffices to offset the comparatively high annual rainfall (28 to 32 inches), so that this is a province of pronounced xerophytic grass formations, but still a transition from the mesophytic Austro-riparian to the xerophytic Lower Sonoran zone. In its temperature relations the province stands almost on the transition to the Upper Sonoran and Carolinian zones respectively, thus differing notably from the Rio Grande plain province which passes into semitropical.

Pure grass formations.— Ecologically the grass formations are strongly xerophytic and partake of the characters of the grass vegetation of the more westerly plains, though in a moderate degree. As already seen, the mean annual rainfall is sufficient, other things being equal, to give existence to semi-mesophytic formations. But the periods of brilliant sunshine and dry air which prevail, especially during the growing season, very quickly dry out the superficial covering of soil and drive vegetation into the resting stage. Under present conditions of pasturage the grass covering has been sadly reduced from its former occurrence. Formerly it was very compact and luxuriant. With the breaking up of this, moisture relations have changed, and the formation is now more xerophytic. Floristically it is impossible to say, with the meager data available, how the association of species compares with that of prairies and plateau plains westward, or to what extent the formation has changed under pasturage. It is certain from the general aspect of the formation, however, that the dominant species here are not dominant ones on the more western plains. In brief, the ecological type known as prairie grasses exists here, as distinguished from the high plains type.

The grass vegetation of the Grand prairie is accompanied by a very abundant vegetation of prairie annuals and herbaceous perennials, with lignescent, tuberous, or bulbous underground parts. These assist in giving the province individuality as a grass formation.

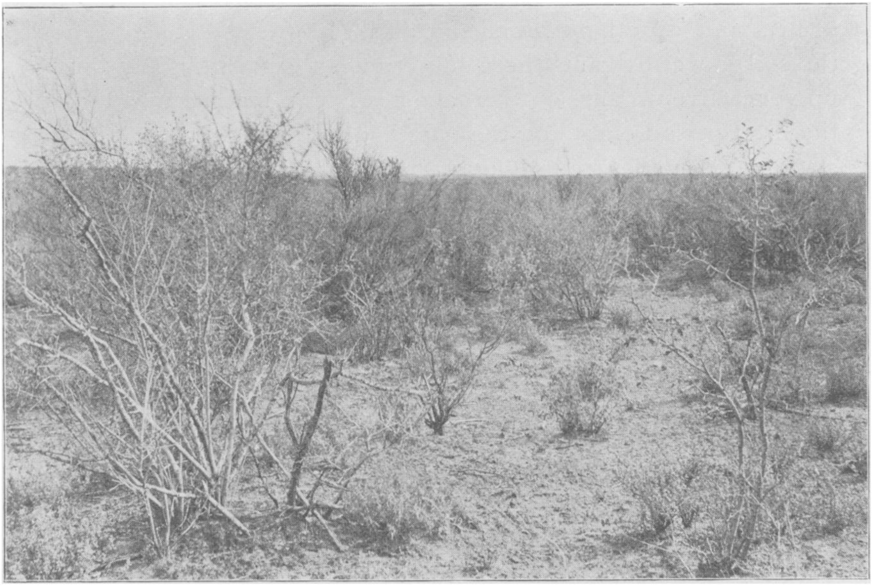

FIG. 7.—Rio Grande chaparral at Laredo: sage (Leucophyllum), "all thorn" (Koeberlinia), Mexican persimmon (*Diospyros Texanum*), and eight or ten other species.

Formations of prairie annuals.—Since the most conspicuous formations of this kind occur in other provinces, this type will be discussed later under a separate heading.

Chalk soil formation of herbaceous perennials.—The species associated in this formation number perhaps thirty-five or forty. It occurs throughout the province on the thinnest soils, but comes out especially on bare chalk slopes. Sometimes a single species prevails upon such places, but commonly there occurs a mixture embracing nearly all the species. Thus a careful collection upon a typical chalk area will yield more than three fourths of the species of the typical formation (*fig. 14*).

In all species the underground parts are reservoirs of food (and not infrequently of water) protected against the extremes of heat and drouth to which the arid soil is subjected. When the soil is wet by rains these subterranean organs quickly throw up vegetative organs, and perhaps flower and mature fruit before the brief period ends and they are again driven into the resting stage. The underground parts are of several types, as succulent fibrous roots with a thick zone of mucilaginous or saponaceous tissue (*Krameria secundiflora*, *Yucca rupicola*); woody subterranean tuberous caudex (*Liatris pycnostachya*); mucilaginous bulbs with impervious coats (Allium, Cooperia), and deep irregular or fusiform roots with hard flinty (sclerenchymatous) coat (*Asclepias decumbens*).

THE CENTRAL DENUDED REGION.—The granite and Carboniferous areas and the upper cross timbers together constitute a belt lying below the western escarpment of the Grand prairie, where the prairies are more or less interrupted by a more broken relief, which in part of the granite area becomes positively mountainous. This belt is marked on the more level areas by a surface covering or by deep beds of sand and gravel, where conditions favor the occurrence of an open timber formation and even a close forest covering in the upper cross timbers. Discussed from the standpoint of grass formation, the granite and Carboniferous areas (Burnet, Brownwood, and Palo Pinto countries of Hill, see *fig. 1*) are open-timber grass prairies, which with the spread of the mesquite (*Prosopis juliflora*) are losing their last remnants of pure grass formation.

The grass formation of this belt (the upper cross timbers not included) appears to have about the same character as that of the sand plains of the Rio Grande plain. The ecological conditions are very similar except as to temperature, and the results of this difference are apparent even superficially in the absence of certain semi-tropical species common at the south, and in the presence of Upper Sonoran or Carolinian species whose range extends into the middle northern states.

THE RED BEDS PROVINCE.—The vast level plains of reddish, chocolate soil make of this province one of the most unique features of the entire Texas region. This geological formation underlies the Staked plains, and has been exposed by the erosion of that area in the Pecos and Canadian river valleys. But the red beds plains lie between the Staked plains and the Grand prairie (more accurately the upper cross timbers), a width of 150 miles, and stretch away through Oklahoma and southern Kansas, a distance of 400 miles. Erosion and weathering have left wide, flat stretches of reddish landscape, either covered with fine, chocolate, silty sand, or exposing the bare rock. Violent bursts of rainfall wash away acres of prairie, often to the depth of several feet, carrying the chocolate flood silt to the coast country. Within the Texas region there are no large relief features in the red beds province, although the broad erosion valleys have to a certain extent the "Bad lands" aspect. The great extent of this province and its geographical position give it climatic relations which are apparent in the character of the vegetation.

As to atmospheric moisture, the stretch of 150 miles (the breadth of the province) from east to west means a variation in rainfall from 27 to 20 inches, and of evaporation capacity from 50 to 65 inches. The vegetation of the western part of the province has a more extreme xerophytic character than that of the eastern part. The northeastern parts sustain extensive mesophytic or semi-mesophytic culture formations with reasonable certainty. It is particularly a wheat belt. Toward the western border these formations become impossible except with seasons of higher rainfall.

As to temperature, while the entire province falls in the Lower Sonoran zone, its position as a whole far to the north of the Rio Grande plain gives it floristic relations more in common with the Upper Sonoran areas to the north. But within the province itself there exists this diversity, that the southwestern border receives much from the arid Sonoran flora of the southwest, at the northeast the incoming flora is a semi-mesophytic one from the northern prairies. This relation to the flora northward is promoted by the continuation of the red beds formation as far as southern Kansas.

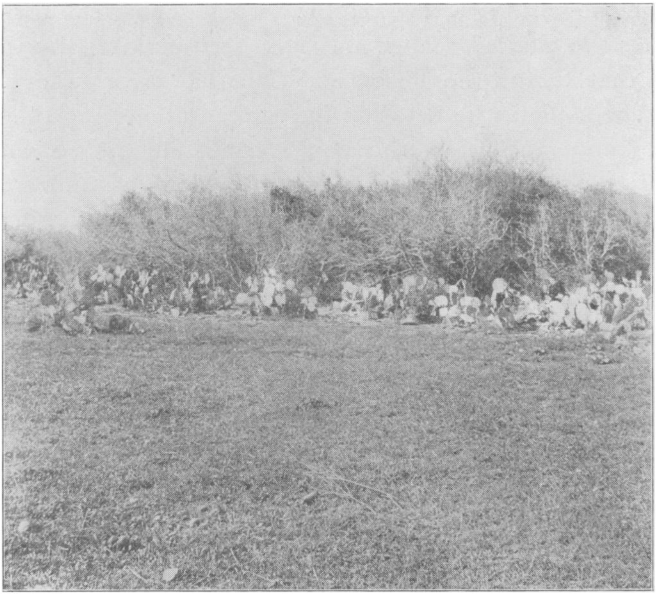

FIG. 8.—Edge of chaparral thicket, Port Lavaca.

The ecological conditions are most favorable for a pure grass plains formation. While it lies beyond the zone of chaparral formations, the mesquite already covers most of the western half of the province, undoubtedly modifying the structure and content of the grass formation. As to the general type of grass formation, the semi-arid climate makes of this a characteristic dry grass plains flora: Without a more specific study of this flora it will be impossible to show satisfactorily wherein lies its individuality as compared with the Grand prairie on the east and the Edwards plateau and the Staked plains on the south and west. It is probable that there is a real distinction, and that it lies chiefly in the peculiarities of the red beds formation. Two specific formations are constantly to be distinguished, (1) the *Hilaria Jamesii* formation, which occupies the lower stretches where sandy loam lies deeper, and appears like a vast field of heavy cultivated hay; and (2) the *Aristida fasciculata* formation, which occurs on ridges alternating with the lower areas of *Hilaria Jamesii*, and in its turn presents large tracts of waving grass fields.

Formations of prairie annuals.—It is not possible at present to say to what extent or wherein the prairie annual formations are distinct from those of other provinces. The soil conditions are such as to favor many species devoted to sandy soils. In the southern part of the province there are species from the south and southwest. At the north the prairie annual flora of Oklahoma and Kansas, in the same longitude, appears to be largely predominant. These formations prevail in such abundance in the case of some species as to form an important factor in the foragē supply, especially in the early spring, when there is a solid mass formation. This disappears before the climax of the grass vegetation season (*fig. 17*).

The Great plains proper.—There are included in this region three provinces of the higher plains, namely Edwards plateau, the Staked plains, and the Stockton plateau (*fig. 1*).

THE EDWARDS PLATEAU.—This province forms the continuation of the Great plains east of the Pecos, from the southern limit of the Staked plains to the downfall at the Balcones escarpment overlooking the Rio Grande plain. The entire southern half between the Colorado and Devils rivers is marked by such deep erosion as to be mountainous. While a grazing country, this is not characteristically a grass plains, but a timbered area, and hence to be discussed especially under timber formations. But the grass vegetation even here contests for predominance, except on the most rugged hills.

The plains prairies.—To the northwest there is an area of the Edwards plateau which has not yet come to the stage of active and deep erosion, but is a typical open level plains country, with low relief lines of erosion remnants, and draws which lead into the cañons of the southern erosion area. This plains prairie is embraced approximately in the counties of Upton, Glasscock, Stirling, Concho, Crockett, Sutton, Schleicher, Tom Green, and Irion.

This Cretaceous area, both by its altitude and its westerly position, shares climatic conditions to a marked degree with the Stockton plateau and the Staked plains. As a result, the grass vegetation is of a more xerophytic character than in any of the provinces previously discussed. It is, in fact, almost fairly within the "short grass" country. Like the Grand prairie, this Cretaceous formation increases the xerophytic tendencies, so that here we find again a strong element in the perennial vegetation, which is more suffruticose than herbaceous, and made up of species with more xerophytic aspect and with affinities to the flora of the trans-Pecos provinces. But this element is in every way the counterpart of the chalk soil lignescent vegetation of the Grand prairie. In addition, the chaparral formations of the Stockton plateau and southwestward are encroaching upon this area.

THE STAKED PLAINS.—The Staked plains of the Texas region are simply a continuation southward of the Great plains area of western Nebraska, Kansas, and eastern Colorado, but cut off from the main area by the deeply eroded channels of the Canadian river on the north, and the Pecos on the west. To the north of the cañon of the Canadian river, Texas contains also a portion (the Pan Handle) of the main body of the plains. "This province is a vast constructional plain made up of flood dĕbris from the mountains at whose base it lies. This mass of loose unconformable stuff is a monotonously flat plateau plain, whose only surface relief is the billowy swells and the shallow saucer-like depressions" (Hill). The open, porous, often sandy texture of the soil furnishes a favorable receiving area for rainfall. The soil water level is too far beneath the surface to be drawn upon even by deep-rooted trees. The vegetation is dependent, therefore, upon the immediate surface for its moisture, and alternates quickly between active growth and the dormant conditions according as the surface is moist or dry. But the porosity of the soil enables it to retain a larger percentage of precipitated moisture, so that the xerophytic conditions are not so extreme as the low rainfall (15 to 18 inches), the high altitude (3500 to 4000 feet), the high evaporation capacity of the air (60 to 70 inches), and its high velocity would lead us to expect. The Staked plains do not terminate at the south in an escarpment, but pass into the plains portion of the Edwards plateau by a broken series of outlying buttes and sand hills and plains. These sand plains not only form the transition from the Staked plains, but extend northward nearer their western side beyond the center of this province.

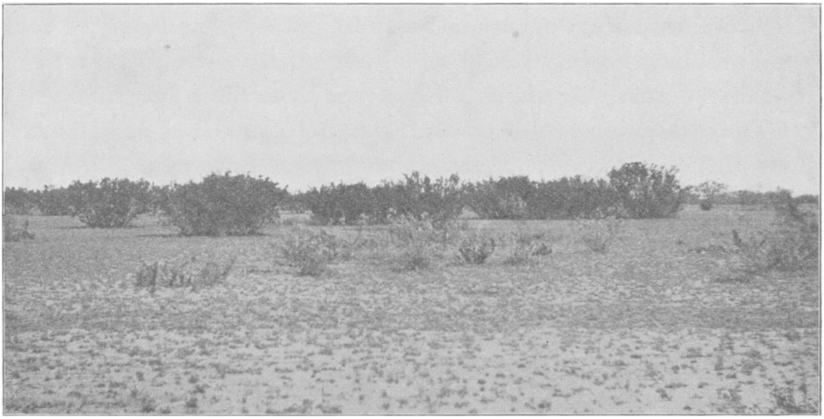

FIG. 9.—Characteristic occurrence of *Acacia amentacea* or black chaparral; on silty clay débris plain near Eagle Pass.

In its temperature relations the Staked plains is mainly Upper Sonoran. The transition from Lower Sonoran is made about the 3500 foot contour. Beginning at the southern limit of the plains, the Lower Sonoran vegetation, notably the chaparral formations, is represented in great strength. In going northward, ascending the plains, this vegetation becomes gradually more dilute, finally leaving a pure grass plain. The most apparent index of transition is furnished by the mesquite, which persists long after every other Lower Sonoran shrub has disappeared. Leaving a jungle of large mesquite below the escarpment, one comes upon a reduced growth upon the plains above, which becomes more and more dwarfed until at 3500 feet it is a mere clump of switches a foot tall, disappearing then absolutely. The same transition occurs in ascending the plains from the red beds province north of Red river, and where the Canadian cuts its cañon across the plains a Lower Sonoran flora has followed.

The grass formation of the summit plains is a solid grass floor of the short buffalo grass type. These grasses, in harmony with the sudden transition from moist to arid conditions, are adjusted to rapid changes from the dormant condition to luxuriant growth, and with the well-known characteristic that the growth already made when dry periods come on becomes perfectly cured as it stands, retaining all of the nutritious qualities which make these grasses economically valuable. All that remains alive during the dry periods are segments of the stem, which may be regarded as equivalent to buds or tubers or rhizomes. These are especially rich in carbohydrates. They are not underground nor connected with the soil by living parts, but merely anchored by the dead fibrous roots of the old growth. The cured grass serves naturally as a protective covering for the dormant living parts, although these are not often killed when the dry covering is burned off. Indeed, it is this quality of being able to endure fires that gives to these grasses the great advantage they possess in their constant struggle against woody vegetation (*fig. 23*).

The herbaceous species which accompany the grass vegetation are chiefly annuals. The lignescent rooted perennials so characteristic of the Cretaceous plains and prairies are mostly wanting, which is in harmony with the open porous soil texture. The very abundant *Yucca angustifolia* is an exception to this fairly constant condition. As to their affinity floristically, these annual species, while containing a considerable element common to Texas prairies south and southwest, are those which range over the whole stretch of plains to Nebraska and the northwest, thus indicating more positively the Upper Sonoran character of the province (*fig. 18*).

The true value of the zonal areas of the Staked plains is not strongly brought out, because the dominant grass vegetation is not so sensitive to temperature differences. Yet it seems pretty certain, though not yet established, that some of the very important species of grasses found in southern and trans-Pecos Texas and north Mexico do not extend upon the Staked plains, but that rather the floristic content of the formation agrees with that of the plains northward.

The grass formation is broken on the sand plains of this province because of the shifting character of the sands. This sand zone according to Dr. Havard, is entered upon going about twenty miles west of Odessa. "It extends thence south and east nearly to the Pecos and north to the very center of the plains. In this zone are the sand hills, a dreary chaotic belt of reddish sand, tossed by the wind into hillocks, cones, and ridges of various sizes and shapes."[7]

The lower belt of the sand zone marks the transition from Staked plains to the Cretaceous Edwards plateau. This is the only portion of the sand plains of which we have data as to the plant formation. Dr. Havard says of it: "The only grasses seen were a stout Andropogon (near *A. furcatus*) three to five feet high, with running roots holding the loose soil in their meshes; a Sporobolus (probably a form of *S. cryptandrus*), likewise erect and tall; and a large form of *Cenchrus myosuroides*." This indicates that the characteristic plains formation is entirely wanting. The herbaceous annuals are also those which prefer sandy soils. It appears from Dr. Havard's report that woody vegetation is the more dominant formation.

THE STOCKTON PLATEAU.—This is a subdivision of the

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[7] HAVARD, Contrib. U. S. Nat. Mus. **8**: (no. 29) 1885.

Edwards plateau, cut off by the cañon of the Pecos river. On the west the province adjoins the eastern front ranges of the mountains. Most of this area is a typical grass plain formation, of the general type found on the Staked plains and on the plains portion of the Edwards plateau. It will be seen that nearer the Rio Grande the surface is more broken, and that here woody vegetation predominates, also that the chaparral formation is encroaching even upon the level grass plains.

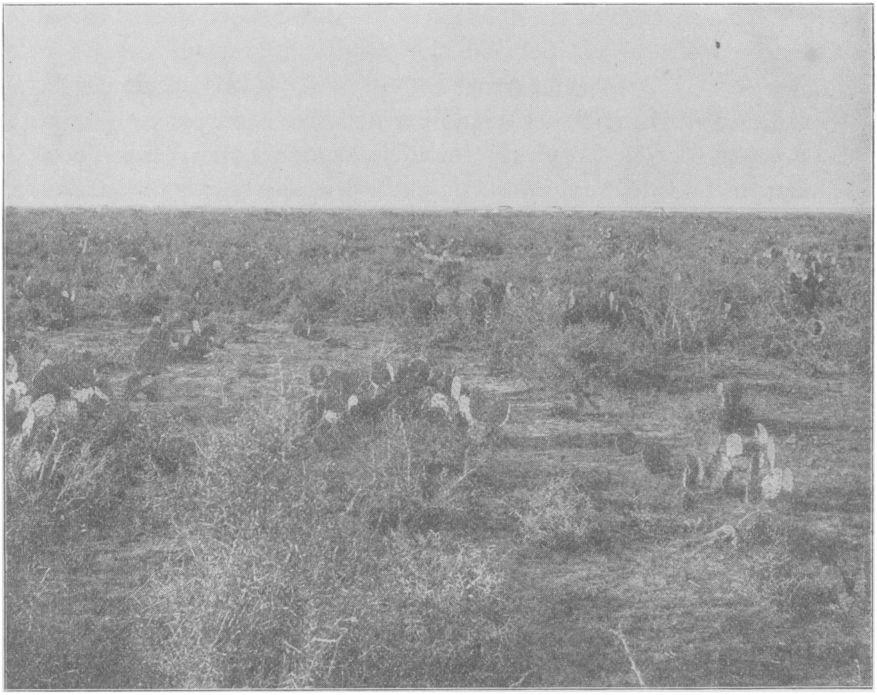

FIG. 10.—Chaparral formation at Corpus Christi; the growth shown is not so tall as that which covers the country generally in this region; the genera are chiefly Opuntia, Condalia, Zizyphus, and Celtis.

Compared with the Edwards plateau, this province as a whole is more elevated, and is in a zone of less rainfall and of greater evaporation capacity. It is more intimately a part of the arid plateau area of the Lower Sonoran zone, wich embraces north Mexico, southern New Mexico, and Arizona, and while it is only surmised that the grass formation would show this floristic relation, it is certain that other formations show it in a marked degree.

MOUNTAINS AND SOUTH PLATEAU SLOPE.

The Rocky mountains proper terminate before reaching the Texas region. The mountain axis continues southward, however, as an elevated plateau whose surface is much cut up by isolated mountain masses, some of which exceed 9000 feet in altitude. These masses are composed of Carboniferous limestone and sandstone, of Cretaceous limestone, and of igneous material. The high plateaus among them are mostly bolson basins filled with the débris of their bordering mountains. The soil conditions here and the moisture conditions growing out of these furnish the direct causes which operate to determine the distribution of plant formation in a region which possesses extreme xerophytic conditions independently of edaphic factors.

Viewed from the standpoint of the grass formation, this is a region possessing a grass floor climate in a surprising degree, for although the mountain masses are in some instances high and rugged, and covered with woody vegetation, the slopes of most of these up to 6000 and 7000 feet, the foothills, the wider plateau plains (for example, about Marfa and northwestward), and even portions of some of the desert bolsons, have a continuous grass formation. But in the mountains of the Great bend and their intervening bolsons (except in the Rosillos mountains, where good and available range grasses are found, according to Havard), on bolsons with loose wind-swept débris, and on arid gravelly mesas, there is only the most scattering bunch-grass formation, or even no permanent vegetation at all.

The bolson basins of this region, owing to the distribution of sedimentary filling, are lowest at the center and undrained. Consequently, the drainage water gathers at this place, in many cases accumulating in ponds or rather large lakes, and in all cases making alkaline flats of varying degrees of saltiness. The higher, less alkaline slopes of these bolsons are often covered with grama grass formation characteristic of the region. The alkaline flats, of course, possess a halophytic vegetation, of which salt grasses form a prominent part.

On the whole, the grass vegetation of the mountain and south plateau provinces falls under three types of formation: (1) the close grass floor formation; (2) the open bunch grass formation; and (3) the salt grass formation. Of these the third will be discussed under the special head of "halophytic formations."

The open bunch grass formation is floristically equivalent to the close grass floor formation. The open and bunched character of the formation is due to extreme dryness, and especially to the instability of the loose finer igneous débris, or the coarser gravelly or stony nature of the soils.

The close grass floor formation may be designated "grama grass formation," from the popular name of the one to several prevailing species. In this formation, the great majority of species making up the formations of the eastern provinces have been sifted out by increasingly arid conditions, and only those remain which mark the extreme limit of xerophytic adaptation in grasses. A summary of the adaptation features of this type of formation shows: (1) rapid transitions from active to dormant conditions; (2) great resistance to extreme dryness and heat (including fires) while in the dormant stage; (3) equally great recuperative power after extreme treatment, including apparent extermination from a given area; (4) large food storage of fats and sugars in portions which retain vitality during dormant periods, thus rendering quick growth possible; (5) the quality of perfect drying *in situ*, thus not only covering the soil and holding it in place, but also protecting the vital parts.

PURE FORMATIONS OF PRAIRIE ANNUALS IN THE PRAIRIE PLAINS.

In the preceding discussion of grass formations, the herbaceous annuals of the prairies have been treated simply as accessory elements in the formations, but of value in characterizing the formations differing somewhat in temperature and moisture conditions. But the annuals of the prairies in the west Texas region, as well as those in other parts of the Lower Sonoran zone, constitute a vegetation phenomenon which periodically overshadows everything else. This phenomenon is the annual wave of vegetative growth and floral display which sweeps over the prairies, temporarily submerging the grass vegetation itself. In the mutual adjustment of grasses and herbaceous annuals in this climate, the latter, mostly pure mesophytes, must take advantage not only of the returning rainy season but of the optimum period preceding the intense summer heat, and of the absence of competing grasses at that time of the year. It is a matter of record among cattle men that in the early spring, when grass forage is scarce, their herds often feed largely upon the

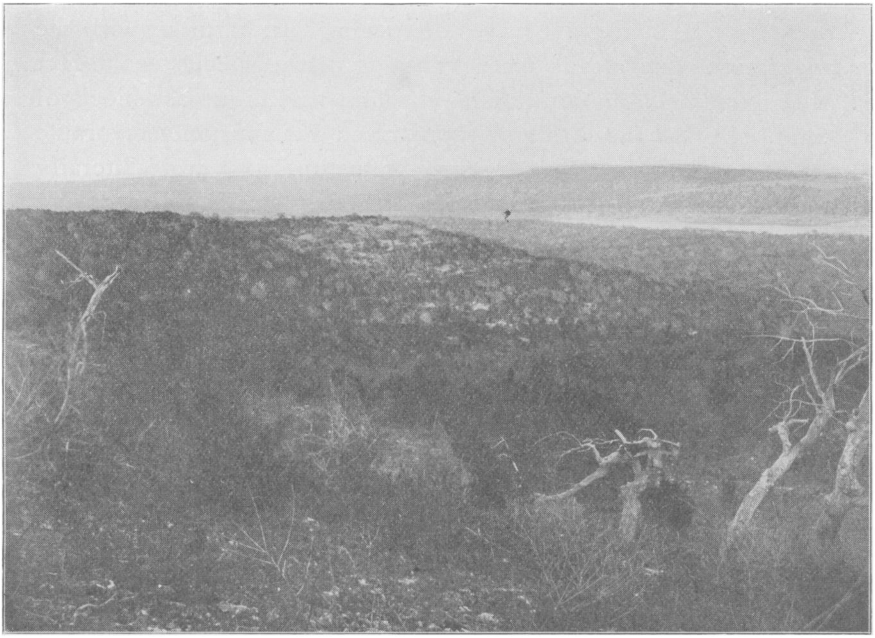

FIG. 11.— Hills covered with xerophytic timber, central mountainous region of Edwards plateau.

abundant young vegetation of these prairie annuals. Thus the "tallow weeds" (*Actinella linearifolia* and *Amblyolepis setigera*), which cover many miles of range, are much prized. Not only does this annual vegetation sweep as a wave over the prairie in the early spring, but the individual species mass themselves in pure formations of incredible compactness and extent (*fig. 19*). Thus there may be successive waves of species. In harmony with the adaptation which leads to the massing of the species is the fact of the brilliance of floral display. This results in vast sheets of color. During the spring of 1900, which was unusually favorable for vegetation, the virgin prairie plains of Texas were literally a sea of color. In his survey of the Rio Grande plain during May, Vernon Bailey noted over twenty species which, as he expressed it, either occupied exclusively "acres of prairie" or "made miles of solid color." This was the case in the lower Rio Grande country (Corpus Christi to Brownsville) previous to May 10. The season of display ended about four weeks later on the northern boundary. At Austin by the first of July (often even two weeks earlier) a solid grass formation occupies the ground which had just previously been exclusively occupied by the "blue bonnet" (*Lupinus subcarnosus*). The continuity of grass formation seems in no wise disturbed by the periodical dominance of the annuals.

The species of these formations are of course dependent upon seed for their recurrence, and consequently are subject wholly to the caprice of rainfall during March and early April. When, as frequently happens, there is no rainfall of consequence during this period, the display of prairie annuals is very much reduced. Their adaptations are in the direction of seasonal adjustment rather than toward meeting xerophytic conditions.

II. WOODY VEGETATION.

Since the region under discussion includes only so much of Texas as is marked by a distinctly xerophytic vegetation, it follows that, except for river bottom and sheltered cañon timber, the woody vegetation is as a whole one of xerophytic aspect.

But it is of varying degrees of xerophytism according to its relation to the zones of decreasing moisture from east to west, that in the eastern provinces possessing some of the elements of the vast mesophytic forest of east Texas, while the extreme of xerophytism is reached in the desert bolsons of extreme west Texas. Recalling the common conception of the west Texas region as a grass country, it becomes a matter of surprise to learn how great is the proportion covered by woody formations, that is arborescent or shrubby vegetation in sufficient amount to form the chief covering.

This includes the following areas: the erosion area of the Edwards plateau; the hills, bluffs, and escarpment of the Grand prairie; the granite, Carboniferous, and upper cross timber areas; the higher mountain slopes and summits of the trans-Pecos mountains; the escarpment of the Staked plains and the Callahan divide; the chaparral of the Rio Grande plain, of trans-Pecos Texas, and of the lower Staked plains and adjacent Edwards plateau; the open streamways and the cañons; and finally many thousands of miles of mesquite-covered prairie. The energy and rate of encroachment of woody vegetation during the past half century lead one to believe that there is scarcely an area of consequence in the state that woody vegetation of some type will not occupy and cover more or less completely, granting of course that no artificial means are employed to check it.

The woody vegetation is here discussed under several types of formation, based largely upon moisture relations.

ARBORESCENT VEGETATION.

XEROPHYTIC FOREST FORMATIONS OF THE EROSION MOUNTAINOUS AREA OF THE EDWARDS PLATEAU (including the hill, bluff, and escarpment timber of the Grand prairie).—That portion of the Edwards plateau embraced between the Colorado and Devils rivers, and extending back 100 to 125 miles from the Balcones escarpment (southern downthrow of the Great plains) is very deeply cut by erosion channels, until the appearance is that of a mountainous country. Here are found in full operation those agencies which have worn so much of the surface elsewhere from a higher to an approximately level lower plane. The Cretaceous limestones, which on the grass plains portion of the Edwards plateau lie still unbroken, have here been cut through and exposed on all sides, thus not only offering lines of penetration for tree roots, but moisture facilities not available from an unbroken level surface. By this erosion, also have come about unequal conditions as between the summits and slopes of the hills, and the gorges and cañons between them. Certain Cretaceous formations, friable on exposure to weathering, outcrop on the hill slopes or summits, thus exposing an unstable foundation for vegetation. On these outcrops, often entirely bare, certain very hardy species can secure a foothold, and so anchor

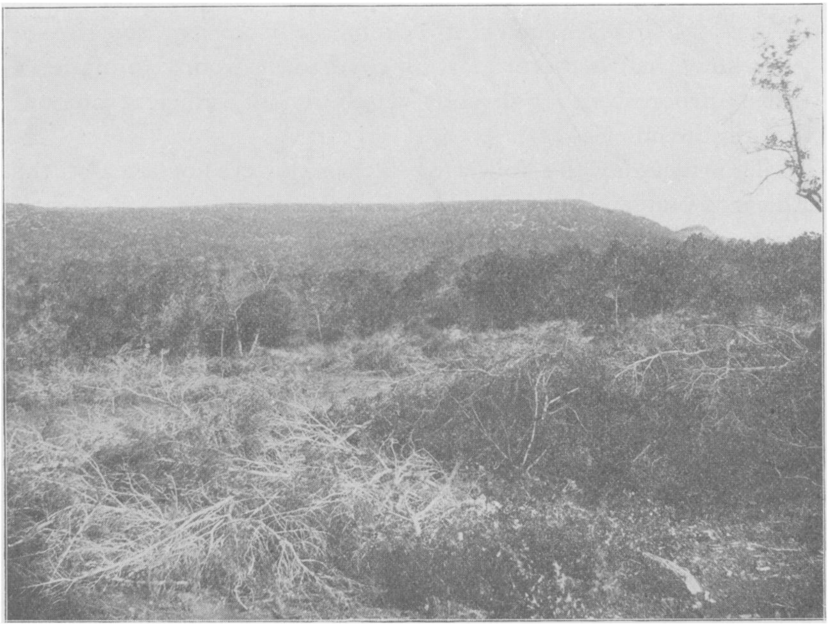

FIG. 12.—*Juniperus sabinioides* formation; a prominent feature in the xerophytic timber region of the Edwards plateau province.

this crumbling rock, even permitting a soil accumulation. The existence of similar conditions in the exposed formations in the Grand prairie results in carrying the timber vegetation over the hills and bluffs and bordering escarpments of this province far to the northward of the main body (*fig. 11*). This timber formation is an open stunted forest covering, which suffers extensive interruptions, but continues in spite of this to be the dominant vegetation feature of the areas just described. On some high arid divides it becomes reduced almost to shrubby dimensions.

Floristically, the chief elements of this vegetation are Lower Sonoran, of which many species range southwest into the Mexican mountains, or westward across the continent. In the western part of this province the presence of western mountain species is very marked. At the east there remains a strong element common to the Austro-riparian and Carolinian zones; but, aside from these indications of relationship, the province has a strong individuality. This is well shown by the fact that Austro-riparian and Carolinian species (when not present in the cañon timber) are vicariously represented by species stamped with the climatic characteristics of the region. Perhaps the most noteworthy case is that in which *Juniperus Virginiana* is succeeded by *Juniperus sabinoides*, the latter being a most characteristic xerophyte.

As to the content of the forest formation, this may vary from a pure formation of one species to a more or less uniform mixture of 50 or 60 per cent. of all the species. This variation is generally due to variations in soil condition. For example, a pure formation of *Juniperus sabinoides* may be due to an extensive exposure of very friable limestone like the Glenrose beds. In some cases the prevalence of a single species is due to the accident of its having gained the ground first. The following species formations are the most notable in this province:

Juniperus sabinoides formation.—This is the most important formation, partly because of its ecological relations, partly from its economic value. The formation is popularly called "cedar brake." Such brakes may be almost impenetrable over many square miles. The tree branches diffusely from the ground up, making a compact oval outline when standing free, and a dense interlacing of branches in close formation. Frequently at the ground the trunk itself divides into several approximately equal members. A pure formation of this juniper occurs characteristically where a friable limestone exposure lies almost bare of soil except a loose débris collected by the forest itself. Where such an outcrop occupies a slope whose angle is sufficient to make the friable rock surface unstable, an open cedar formation is the only woody vegetation present (*fig. 12*).

Aside from the very general use made of cedar in commercial ways, it occupies an important relation to moisture and soil conditions. Not only is the formation found to occupy areas where soil cannot accumulate except for the presence of this growth, but when cut or burned off it tends to reoccupy the ground most vigorously and to encroach upon the other species.

Quercus breviloba formation.—This is the so-called "mountain shin oak" of central Texas. On the summits of the high divides, where a thin soil is underlaid by unbroken limestone, the timber vegetation becomes very much dwarfed. In such cases the shin oak often becomes the dominant species and sometimes the only one, forming scrub thickets known as "shinneries." The mature plant may not exceed three or four feet in height. A familiar illustration of shin oak country occurs on the high divide between the San Gabriel and the Colorado rivers in Burnet county.

Quercus Virginiana formation.—This is in reality a dwarfed live oak formation which covers lower hill slopes or flats where the thin surface covering of black soil is strewn with coarse fragments of the broken underlying limestone. Such country, from its stony character is known as "hard scrabble," and the timber covering, often almost wholly of dwarfed live oak, is dwarfed and gnarled into a fitting counterpart of the ground structure (*fig. 13*).

ENCROACHMENT OF THE CRETACEOUS TIMBER FORMATION.—The forest covering of the erosion area tends not only to renew itself when removed, but it is a vigorous agressor upon previously open untimbered areas. This persistence may well be turned to account in any plans looking toward the maintenance of the forest covering on the more arid hills for prevention of soil erosion and destructive floods.

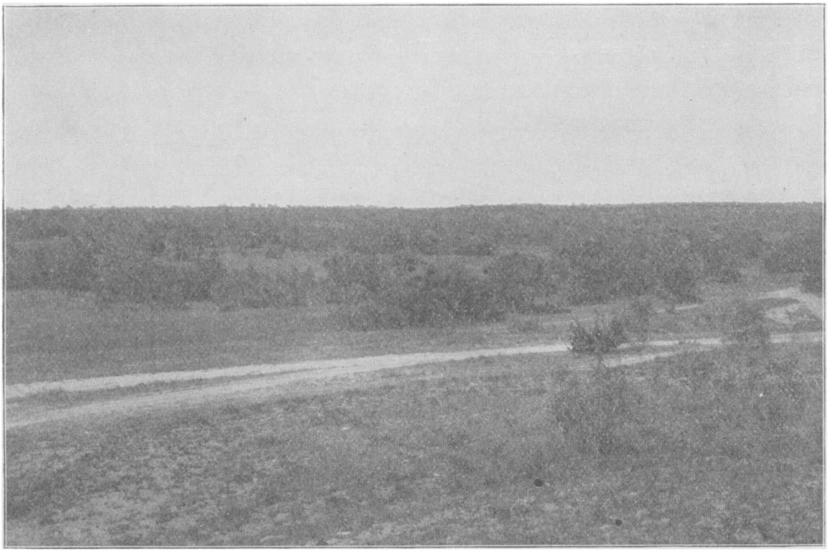

FIG. 13.—*Quercus Virginiana* (mountain form) formation; Cretaceous hills fifteen miles west of Austin.

XEROPHYTIC FOREST FORMATION OF THE MOUNTAIN SLOPES OF TRANS-PECOS TEXAS.—This formation is the counterpart of that just described for the erosion area of the Edwards plateau. It is a part of the forest covering of the arid mountain slopes of the southwest, including south Colorado, New Mexico, Arizona, and northern Mexico. Its area in Texas is practically limited to the upper slopes of the mountains in the great bend of the Rio Grande (above 6000 feet); to the dry upper cañons in these mountains; to the middle slopes of the Guadalupe and Davis mountains and their dry cañons.

The ecological conditions of these mountain slopes are more extreme than in the erosion area of central Texas, as shown in the following data. The annual rainfall is from 14 to 26 inches (approximate averages for each area respectively); the evaporation capacity is from 80 to 60 inches; the extremes of daily temperature in the trans-Pecos mountains is much greater than in the central region. Consequently the arborescent vegetation is one of more absolute adjustment to xerophytic conditions, and the semi-mesophytic species found in the central erosion area are either wholly excluded from the trans-Pecos area or relegated to the watered cañons. Of the arborescent species, *Pinus edulis*, *Juniperus pachyphloea*, *J. occidentalis*, *J. monosperma*, *Quercus grisea*, and *Q. Emoryi* are the principal ones. Not all of these are confined to the mountain slopes, for in watered cañons some of them form heavy timber of large size and good quality; but on the slopes their growth is dwarfed, the wood hard, the stems gnarled and misshapen, and they stand in a scant open formation.

The timber formation just described extends to certain physiographic features east of the Pecos river. These are the Staked plains escarpment, the remnant buttes of the Callahan divide (at least west of the 100th meridian), the sand hills of the southern Staked plains, and the cañon bluffs of the Devils and Nueces rivers. In the last instance, it is very dilute, being lost in the local formation, but in the other cases it is practically the only timber.

On the escarpment of the Staked plains, even as far as the northeastern border, there occur *Pinus edulis*, *Juniperus occidentalis* (in many straggling groves of small growth, according to Havard), and *Quercus grisea*. On the remnant buttes of the western half of central Texas there are close formations of a much dwarfed *Q. grisea*, in which this species attains a growth of only two to five feet, covering the ground in true chaparral fashion. Here also is found a very scattered formation of *Juniperus occidentalis*, which occupies also the lower mesas, becoming one of the chaparral species covering them.

On the sand hills of the lower Staked plains region one of the western mountain oaks (*Q. undulata* or *Q. Gambelii*) occurs in low thickets. To this region and the buttes and mesas eastward the trans-Pecos chaparral formation extends, and such reduced growths of *Quercus* and *Juniperus* as occur here become identified with the chaparral.

[*To be concluded.*]

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